Dec. 12, 1995 Name: ____________________________

# Final Examination

# NE-630: APPLIED REACTOR THEORY

**PART A:** Closed books and notes. Hand in before beginning Part B.

1. Define in words the physical meaning of $k_\infty$ and of each factor in the four-factor formula $k_\infty = \epsilon p \eta f$. *[8 points]*

2. Make a sketch of how $k_{eff}$ and each of the four factors in the four-factor formula for $k_\infty$ varies with the moderator-to-fuel ratio $N_M/N_F$ in a homogeneous system. Use the same figure for all four factors and indicate an approximate vertical scale. NOTE: the origin represents a system composed of only fuel. *[6 points]*

3. Explain how and why each of the four factors in the four-factor formula for $k_\infty$ changes if a homogeneous core is converted into a heterogeneous core with the same fuel-to-moderator ratio. *[6 points]*

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**Part B:** Open books and notes. Begin only after handing in Part A.

4. A bare cubic homogeneous core is critical when surrounded by a vacuum. For each of the following changes, explain what happens to $k_{eff}$ and give a reason for your choice. Consider each change separately. *[10 points]*

   (a) A person approaches the core.

   (b) The core is deformed into a sphere.

   (c) A neutron source is brought near the core.

   (d) The core operates at high power.

   (e) the core is expanded in size at constant mass.

5. An infinite homogeneous slab of thickness $T$ and composed of a purely diffusing material with a thermal diffusion length $L$. The slab contains a volumetric source of strength $S(x) = S_o e^x$ neutrons cm$^{-3}$ s$^{-1}$ where $x$ is measured perpendicularly from one face of the slab. The slab is surrounded by a vacuum. (a) Write the appropriate form of the one-speed diffusion equation that determines the flux density in the slab. (b) What is the most general solution of this equation? (c) What boundary conditions would you use to find values of any arbitrary constants in your general solution? Assume the validity of one-speed diffusion theory. *[10 points]*

6. A uniformly distributed source of 3-MeV neutrons of strength $10^8$ neutrons cm$^{-3}$ s$^{-1}$ is embedded in an infinite water medium. If absorption of neutrons during slowing down is negligible, calculate the energy-dependent flux density at 1 eV in this medium. DATA: at 1 eV, $\sigma_s^O = 3.8$ b, and $\sigma_s^H = 22$ b. *[10 points]*

7. In the center of the core of a 1000 MW(e) BWR, the observed fission rate is $1.7 \times 10^{12}$ cm$^{-3}$ s$^{-1}$ and the observed temperature of the fuel is 800 C. What will be the fission rate at the same location if the temperature is raised to 900 C? *[10 points]*

8. Consider a homogeneous mixture of beryllium and $^{235}$U at room temperature in which the atomic moderator-to-fuel ratio is 20,000. *[40 points]*

   (a) Explain why $\epsilon p \simeq 1$ for this core material?

   (b) Calculate $k_\infty$ for this core material.

   (c) What is the square of the thermal diffusion length, $L_T^2$, for the core material? (*HINT:* Recall that $L_T^2$ is a function of $f$)

   (d) What value of the Fermi-age-to-thermal $\tau_T$ would you use for this core?

   (e) Calculate the non-leakage probabilites for a bare 120-cm diameter sphere of this material.

   (f) Calculate $k_{eff}$ for a bare 120-cm diameter sphere of this material.

   (g) What thermal utilization factor $f$ would make the 120-cm diameter core critical?

   (h) What is the moderator-to-fuel ratio needed to make the 120-cm diameter sphere critical?

   (i) How many kilograms of $^{235}$U are needed to produce the critical 120-cm diameter core?